Pink Bollworm: Expected Reduction in Damage to Cottons Carrying Combinations of Resistance Characters

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ABSTRACT

Pink bollworm, *Pectinophora gossypiella* (Saunders), inflicted less seed damage on glabrous and nectariless mutants, on early maturing strains, and on a stock of complex parentage, designated AET-5, than on commercial cultivars of upland cotton, *Gossypium hirsutum* L. No single character or strain imparted enough resistance to the insect to eliminate the need for insecticidal control. The glabrous and nectariless characters in combination reduced seed damage below that of the single characters but not below the economic level under insect pressure commonly encountered in field plots at Tempe, Ariz. On the assumption that all four independent characters (glabrous, nectariless, early maturity, and antibiosis) acted multiplicatively when combined, we calculated expected maximum and minimum seed damage (as percentages of damage in check cultivars) in hypothetical breeding stocks carrying two, three, and four resistance characters. Results suggested that at least three characters would have to be combined to provide sufficient resistance to reduce seed damage below the economic level. Advanced breeding stocks now available indicate it may be possible to combine several characters without sacrificing yield potential or fiber quality.

KEYWORDS: *Gossypium hirsutum* L., *Pectinophora gossypiella* (Saunders), plant resistance to insects, nectariless cotton, glabrous cotton, early maturing cotton, combined resistance, multiple resistance, insect resistance, insect predators, insect parasites.

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PINK BOLLWORM: EXPECTED REDUCTION IN DAMAGE TO COTTONS CARRYING COMBINATIONS OF RESISTANCE CHARACTERS

F. D. Wilson, R. L. Wilson, and B. W. George[1]

INTRODUCTION

The use of resistant plant cultivars is an ideal method of controlling insects because they reduce production costs and environmental pollution. In some crops, resistance is at a sufficiently high level to effect insect control (*6*).[2] Many individual plant characters, however, do not confer high levels of resistance to insects; resistance must be augmented by insecticides and other control methods. In fact, the most important use of insect-resistant cultivars may be as a component part of pest management systems (*6*, *8*).

The possibility of using combinations of resistant characters in a single cultivar to increase its resistance has been noted (*1*, *4*, *5*, *10*, *11*, *17*). A major problem in cotton, *Gossypium hirsutum* L., as in other crop plants, is the deficiency in agronomic characters often associated with combining several characters in a single breeding stock (*5*, *13*).

Several morphological mutants and breeding stocks of cotton possessing resistance to pink bollworm (PBW), *Pectinophora gossypiella* (Saunders), have been identified (*9*, *16*, *17*, *18*, *19*, *20*). None of these characters provides sufficient resistance to pink bollworm to be adequate alone; however, two characters in combination, nectariless and glabrous, cumulatively decreased seed damage by PBW (*17*).

The possibility needs to be explored that other combinations of characters will increase resistance to a level that will virtually eliminate the need for other control methods. This paper discusses theoretical aspects of this possibility under the assumption that the combined effects of single independent resistance characters are multiplicative.

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[2]Italic numbers in parentheses refer to Literature Cited, p. 5.

METHODS AND MATERIALS

The check cultivars in field screening tests in Arizona and Puerto Rico, 1972-77, included the following: 'Deltapine 16', 'Deltapine 61', 'Stoneville 7A', 'Stoneville 213', and 'Stoneville 256'. The experimental strains and cultivars originated from a variety of sources. Experimental strains that showed less seed damage by PBW than the check cultivars carried one (or sometimes two) of the following resistance characters: pubescence, pilosity (*9*, *18*), glabrousness, nectarilessness (*17*), Okra-leaf or Super Okra-leaf shape (*20*), and early maturity (*12*). One breeding stock, designated AET-5, having a moderate level of antibiosis (*14*), consistently had less seed damage than the checks (*18*).

We will consider only variants in upland cotton, not in the primitive race stocks that have shown resistance (*19*). The highly pubescent and pilose characters are not practical sources of resistance in the United States where cotton is harvested mechanically because of the high percentages of leaf trash in the seed cotton. The pilose gene, H_2, also has a deleterious effect on fiber quality (*18*). We will also not include the Okra-leaf and Super Okra-leaf breeding stocks because we have been unable to separate the effects of earliness (escape) in these cottons from other possible resistance effects.

The mechanisms of resistance are at least partly known in nectariless stocks (limit adult food (*17*)) and in AET-5 (antibiosis as measured by lower pupation in PBW from hand-infested bolls on greenhouse-grown plants (*14*)). The major mechanism is escape in early maturing stocks, usually not considered true resistance but nevertheless effective in reducing seed damage. The mechanism of resistance in glabrous stocks is unknown but is presumably independent of those in the other variants discussed.

Seasonal seed damage by PBW (ratio of damaged to undamaged seeds in four or five samples of 300 to 500 seeds from sequential biweekly harvests, determined by the X-ray method of Wilson and Wilson (*15*) was calculated for each cultivar and test entry. The reduction in seed damage in the test strain versus that in the check was calculated, providing a range in percentages from various tests conducted during several seasons and at two locations. Thus, minimum and maximum estimates were made of the reduction in seed damage attributed to a cotton strain carrying a specific morphological character or otherwise showing a resistance response to PBW.

The expected result of combining two or more independently acting resistance characters in one breeding stock would be a multiplicative reduction in seed damage. For example, strain A, with 75 percent as much seed damage as in the check, when combined with strain B, with 80 percent as much seed damage, would give rise to strain AB, with expected seed damage of (0.75) (0.80), or 60 percent as much damage as sustained by the check (that is, 40 percent reduction). We used this method to calculate minimum and maximum estimates of expected seed damage in cotton strains (as percentages of susceptible checks) postulated to carry various combinations of two, three, and four resistance characters.

The data of Henneberry et al. (*3*), coupled with our data, were used to estimate an economic level of seed damage caused by PBW.

RESULTS

Table 1[3] shows some relationships between seed damage and cumulative lint yield in sprayed and unsprayed Deltapine 16 in 1975 and sprayed and unsprayed Deltapine 61 in 1978. In 1975, cumulative lint yield was significantly lower at both first and second harvest dates in unsprayed than in sprayed plots, which suggests that the economic level of seed damage was below 9.4 percent in Deltapine 16. In 1978, cumulative lint yield was not significantly lower in unsprayed versus sprayed plots at the fourth or fifth of nine harvests (days 250 and 257, respectively), but was significantly lower at the sixth harvest, day 264. These data suggest that the economic level of seed damage was between 7.0 and 10.5 percent in Deltapine 61.

Seasonal seed damage percentages are shown in table 2 for the Deltapine and Stoneville check cultivars grown in various tests during 1975-78.

Table 3 shows the observed maximum and minimum seed damage by PBW (as percentages of Deltapine and Stoneville check cultivars) to experimental strains, each carrying a single character for resistance. Percentages ranged from 85.2 for Stoneville nectariless (compared with the Deltapine check) to 37.0 for AET-5 (compared with the Stoneville check).

Table 4 shows expected maximum and minimum seed damage (as percentages of the relevant check cultivars, table 3), if two resistance characters were combined in a single cotton strain. Percentages range from 69.9 ((0.852 x 0.820) x 100; table 3) for the maximum nectariless-AET-5 combination to 16.0 ((0.433 x 0.370) x 100; table 3) for the minimum early AET-5 combination.

Table 5 presents expected maximum and minimum seed damage if three or four characters were combined in a single cotton strain. Percentages range from 55.6 (nectariless, glabrous, AET-5 maximum) to 5.9 (nectariless, glabrous, early, AET-5 minimum).

Table 6 compares observed seed damage (1) in check cultivars, (2) in glabrous and nectariless cottons, and (3) in those that carry the glabrous-nectariless combination.

DISCUSSION

Our goal is to develop a PBW-resistant cultivar that will reduce seed damage below the economic level without the aid of insecticides. The economic level of seed damage was between 7.0 and 10.5 percent at Tempe, Ariz. (table 1). The data of Henneberry et al. (*3*) buttress this finding. They showed that Deltapine 16 protected with insecticide from mid-July to mid-October (15 applications) sustained 11 percent boll infestation (that is, 11 of 100 bolls had evidence of PBW damage) and had 9 percent seasonal seed damage. Cotton sprayed nine times had 15 percent boll infestation and 12 percent seed damage. Un-

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[3]All tables are grouped in the Appendix.

sprayed plots had 28 percent boll infestation and 19 percent seed damage. Lint yield was significantly lower in unsprayed than in sprayed plots. The generally accepted economic level of boll infestation is 10 to 15 percent (7), which would equate with about 8 to 12 percent seed damage.

In 1975, 1976, and 1978, seasonal PBW damage varied from 19.2 to 60.2 percent in the cultivars (table 2). Therefore, reductions of 48 to 83 percent in seed damage would have been necessary to reach the arbitrary 10 percent seasonal level in resistant stocks. In the maximum damage category, no cotton having a single resistance character reduced seed damage as much as 48 percent below that in the Deltapine and Stoneville checks (table 3). Two hypothetical and one actual stock combining two resistance characters reduced seed damage more than 48 percent (tables 4 and 6). Three of four hypothetical stocks combining three characters and the single one combining four characters reduced seed damage more than 48 percent, but none reduced it as much as 83 percent (table 5). In the minimum damage category, none of the single-character stocks had 48 percent less seed damage than both Deltapine and Stoneville checks, but seven of the eight hypothetical stocks, combining two, three, or four resistance characters, had at least 83 percent less seed damage than the checks.

In 1977, seasonal seed damage was below 10 percent in the check cultivars except for Stoneville 213. Under these conditions, a resistant strain would offer no advantage. On the other hand, it would offer no disadvantage if it had the same yielding potential as the commercial cultivars.

Observed seed damage in the glabrous, nectariless La 15213 (43.2 percent of that in the check) agreed well with the expected value based on seed damage in the glabrous (79.6 percent of check) and nectariless (61.1 percent of check) cottons included in the 1975 test. In 1976 and 1977, we did not include a glabrous cotton, but the glabrous, nectariless La 17801 had 21 and 13 percent, respectively, less seed damage than the nectariless 'Stoneville 731N'.

Our observations and projections suggest that at least three resistant characters would have to be combined to allow self-sufficiency in resistance under the severe pressure that PBW has exerted in upland cotton grown at Tempe. Is it realistic to believe that these characters can be combined in breeding stocks that are equal in yield potential and fiber properties to currently grown cultivars? Most resistant stocks have been deficient in one or more of these characters (*13*, *18*). We also recognize the possibility of other complications in making predictions based on our assumption of multiplicative effects. Biological systems generally do not behave quite as predicted. We are not sure how much earliness can be tolerated without leading to unacceptable yield losses in the long seasons of the southwestern deserts. We can only measure the AET-5 type of resistance by a bioassay and will probably have to select for it in hybrid families rather than in individual hybrid plants.

Another possible complication is how cottons carrying combinations of resistance characters will affect other cotton insects. In both 1975 and 1976, we found lower populations of *Lygus* spp. on glabrous-nectariless cottons than on the checks. In 1975, we also found lower populations of certain predators in glabrous-nectariless cotton, notably *Hippodamia* spp. (adults), *Geocoris* spp., *Nabis* spp. and *Chrysopa* spp. Other predators and parasites were as numerous in the glabrous-nectariless cotton as in the checks, notably several

species of spiders, *Hippodamia* larvae, *Collops* spp., *Orius* spp., and several species of small wasps. We observed no differences in numbers of "horseshoe" stage larvae of cotton leafperforator (*Bucculatrix thurberiella* Busck) in glabrous-nectariless and in hirsute, nectaried cottons in 1977. Henneberry et al. (*2*) found lower populations of *Lygus* spp., cotton leafperforator, *Chrysopa* spp., and *Geocoris* spp. in nectariless cotton than in the nectaried checks.

Populations of *Heliothis* spp. (cotton bollworm complex) have never been high enough in our plots to cause an economic level of damage. Other workers, however, have demonstrated the resistance of glabrous and nectariless cottons to these insects (*5*).

It appears, therefore, that the cottons carrying combined resistance characters that we have tested are probably less susceptible, or at least not more susceptible, to lygus bugs, cotton leafperforator, and *Heliothis* spp. On the other hand, lower populations of certain predators could cause problems.

In spite of these complications, we are optimistic about combining resistance characters in superior breeding stocks. Some cultivars and advanced breeding stocks that carry singly or in certain combinations glabrous, nectariless, and early maturity characters are already being used in our program. Combining glabrous and nectariless and other visible characters such as Okra-leaf and Super Okra-leaf should present no formidable breeding obstacles. Incorporation of earliness and AET-5 resistance will be more difficult. One challenge will be the development of rapid field screening methods that can be used by plant breeders to detect less obvious resistance characters.

Thus, whether we can develop cottons self-sufficient in resistance to PBW remains to be seen. Any increase in natural resistance to this insect, however, should lead to the use of less insecticide by the grower. The resulting cultivar's natural resistance will better adapt it for use as a component in integrated control. For these reasons alone, it seems worthwhile to breed cottons having multiple resistance characters.

LITERATURE CITED

(1) Brazzel, J. R., and D. F. Martin.
1956. Resistance of cotton to pink bollworm damage. Texas Agricultural Experimental Station Bulletin No. 843, 20 p.

(2) Henneberry, T. J., L. A. Bariola, and D. L. Kittock.
1977. Nectariless cotton: effect on cotton leafperforator and other cotton insects in Arizona. Journal of Economic Entomology 70: 797-799.

(3) ________ L. A. Bariola, K. E. Fry, and D. L. Kittock.
1977. Pink bollworm infestations and relationships to cotton yield in Arizona. U.S. Department of Agriculture, Agricultural Research Service, Western Region, ARS W-49, 9 p. [Series discontinued; Agricultural Research Service is now Science and Education Administration-Agricultural Research].

(4) Jones, J. E.
1972. Effect of morphological characters of cotton on insects and pathogens. *In* Proceedings of the Beltwide Cotton Production Research Conferences, p. 88-92. [Memphis, Tenn., January 10-12, 1972.] National Cotton Council, Memphis, Tenn. 38112.

(5) Lukefahr, M. J., J. E. Houghtaling, and D. G. Cruhm.
1975. Suppression of *Heliothis* spp. with cottons carrying combinations of resistant characters. Journal of Economic Entomology 68:743-746.

(6) Maxwell, F. G.
1972. The value and use of insect resistant agricultural crops. *In* Proceedings of the Beltwide Cotton Production Research Conferences, p. 83-85. [Memphis, Tenn., January 10-12, 1972.] National Cotton Council, Memphis, Tenn. 38112.

(7) Noble, L. W.
1969. Fifty years of research on the pink bollworm in the United States. U.S. Department of Agriculture, Agriculture Handbook No. 357, 62 p.

(8) Painter, R. H.
1951. Insect resistance in crop plants. MacMillan Co., New York, 520 p.

(9) Smith, R. L., R. L. Wilson, and F. D. Wilson.
1975. Resistance of cotton plants hairs to mobility of first-instars of pink bollworm. Journal of Economic Entomology 68:679-683.

(10) Stephens, S. G.
1957. Sources of resistance of cotton strains to the boll weevil and their possible utilization. Journal of Economic Entomology 50: 415-418.

(11) ________ and Hong Suk Lee.
1961. Further studies on the feeling and oviposition preference of the boll weevil (*Anthonomus grandis*). Journal of Economic Entomology 54:1085-1090.

(12) Wilson, F. D., and R. L. Wilson.
1976. Earliness, pubescence, and pink bollworm resistance in cotton. Agronomy Abstracts, p. 67. American Society of Agronomy, Madison, Wis.

(13) ________
1977. Lint yields of cottons resistant to pink bollworm. Agronomy Abstracts, p.77.

(14) ________ R. L. Wilson, and B. W. George.
Pink bollworm: reduced growth and survival of larvae placed on bolls of cotton race stocks. Journal of Economic Entomology (In Press).

(15) Wilson, R. L., and F. D. Wilson.
1975a. Comparison of an X-ray and a green-boll technique for screening cotton for resistance to pink bollworm. Journal of Economic Entomology 68:636-638.

(16) ________ 1975b. A laboratory evaluation of primitive cotton (*Gossypium hirsutum* L.) races for pink bollworm resistance. U.S. Department of Agriculture, Agricultural Research Service, Western Region, ARS-W-30, 9 p. [Series discontinued; Agricultural Research Service is now Science and Education Administration-Agricultural Research.]

(17) ________ 1976. Nectariless and glabrous cottons: effect on pink bollworm in Arizona. Journal of Economic Entomology 69:623-624.

(18) ________ 1977. Effects of cottons differing in pubescence and other characters on pink bollworm in Arizona. Journal of Economic Entomology 70: 196-198.

(19) ________ 1978. Field evaluation of cotton in Puerto Rico for pink bollworm resistance. U.S. Department of Agriculture, Science and Education Administration-Agricultural Research, Western Region, Agricultural Research Results ARR-W-2, 10 p.

(20) ________ F. D. Wilson, and B. W. George. 1979. Mutants of *Gossypium hirsutum*: effect on pink bollworm in Arizona. Journal of Economic Entomology 72:216-219.

APPENDIX

Table 1.--*Relationship between seed damage by PBW and cumulative lint yield in sprayed and unsprayed plants of Deltapine cotton cultivars, Tempe and Phoenix, Ariz.*

Harvest day	Entry treatment: Sprayed		Unsprayed	
	Seed damage	Cumulative lint yield	Seed damage	Cumulative lint yield
	Deltapine 16			
	Percent	*Kg/ha*	*Percent*	*Kg/ha*
1975:				
248	[1]1.7	[1]558	9.9	284
262	[1]2.8	[1]1066	9.4	793
	Deltapine 61			
1978:				
250	[1]1.6	633	5.1	659
257	[1]1.3	945	7.0	929
264	[1]1.7	[1]1170	10.5	1048

[1]Seed damage mean significantly different from the other seed damage mean within the same row and year; lint yield mean significantly different from the other lint yield mean within the same row and year (L.S.D.; P=0.05).

Table 2.--*Seasonal seed damage in check cultivars of cotton, Tempe, Ariz., 1975-78*[1]

Cultivar	Test No.	Seasonal seed damage: 1975	1976	1977	1978
		Percent			
Deltapine 16	1	34.2	27.0	5.1	28.6
	2	--	35.9	9.5	--
Deltapine 61	1	--	60.2	--	19.2
Stoneville 7A	1	37.5	44.0	8.3	--
	2	30.4	--	--	--
Stoneville 213	1	--	36.8	15.5	--
Stoneville 256	1	--	54.1	--	22.2

[1]Mean of 4 replications and 4 or 5 harvests, depending upon year and test.

Table 3.--*Observed seed damage by pink bollworm to experimental cotton strains as a percentage of damage to Deltapine and Stoneville check cultivars, Tempe, Ariz., 1974-77*[1]

Cotton strain	Year(s) tested	Seed damage			
		Deltapine		Stoneville	
		Maximum	Minimum	Maximum	Minimum
		Percent of check			
Stoneville nectariless	1975-77	85.2	83.8	76.9	55.3
Deltapine nectariless	1974-77	69.7	56.3	45.9	45.9
Stoneville glabrous	1975	--	--	79.6	79.6
1 x 6-56 early	1975-77	62.3	43.3	56.8	56.8
AET-5	1974-77	82.0	55.6	77.8	37.0

[1]Data are based on means of 4 replications and 4 or 5 harvests, depending upon year(s) tested.

Table 4.--*Expected maximum and minimum seed damage by PBW, as a percentage of the check, when two resistance characters are combined*

Character	Seed damage		
	Glabrous	Early	AET-5
	Percent of check		
Nectariless:			
Maximum	67.8	53.1	69.9
Minimum	36.5	19.9	17.0
Glabrous:			
Maximum		49.6	65.3
Minimum		34.5	29.5
Early:			
Maximum			51.1
Minimum			16.0

Table 5.--*Expected maximum and minimum seed damage by pink bollworm as a percentage of the check cultivar, when 3 or 4 resistance characters are combined*

Characters combined	Seed damage	
	Maximum	Minimum
	-------Percent of check------	
Nectariless, glabrous, early	42.2	15.8
Nectariless, glabrous, AET-5	55.6	13.5
Nectariless, early, AET-5	43.5	7.4
Glabrous, early, AET-5	40.7	12.8
Nectariless, glabrous, early, AET-5	34.6	5.9

Table 6.--*Seasonal seed damage by pink bollworm and seed damage as the percentage of the cultivar checks in smooth, nectariless, and glabrous - nectariless cultivars and breeding stocks of cotton, Tempe, Ariz., 1975-77*[1]

Cotton strain and year	Seasonal seed damage	Seed damage
	Percent	*Percent of check*
1975:		
Stoneville 7A (check)	30.4	100.0
Stoneville glabrous (74-4-153)	24.2	79.6
Stoneville 731N nectariless	18.6	61.1
Stoneville glabrous, nectariless (La 15213)	13.1	43.2
1976:		
Stoneville 213 (check)	36.8	100.0
Stoneville 731N	28.3	76.9
Stoneville glabrous, nectariless (La 17801)	22.5	61.1
1977:		
Stoneville 213 (check)	15.5	100.0
Stoneville 731N	8.5	54.8
Stoneville glabrous, nectariless (La 17801)	7.4	47.7

[1]Means of 4 replications and 4 or 5 harvests, depending upon year.

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